Title of Project：Effects of land conversion from tropical peat swamp forest to oil palm plantations on ecosystem functions and the atmospheric environment

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Research Project Number：19H05666　Researcher Number：20208838
Keyword: Atmospheric environment, disturbance, greenhouse gases, oil palm plantation, tropical peat

【Purpose and Background of the Research】

Tropical peatlands coexisting peat swamp forest were distributed widely in lowlands in insular Southeast Asia, especially in Indonesia and Malaysia, and have accumulated a huge amount of soil organic carbon (peat).

Recently, however, the peat ecosystems have been disturbed severely through deforestation and drainage to develop oil palm plantations. The land conversion makes peat carbon vulnerable and potentially changes the peatlands from a carbon sink to a large carbon source. Figure 1 shows pictures of recent land conversion from a peat swamp forest to an oil palm plantation in Sarawak, Malaysia. A large amount of carbon dioxide (CO_2) was emitted through the land conversion, including deforestation, drainage and biomass and peat burning.

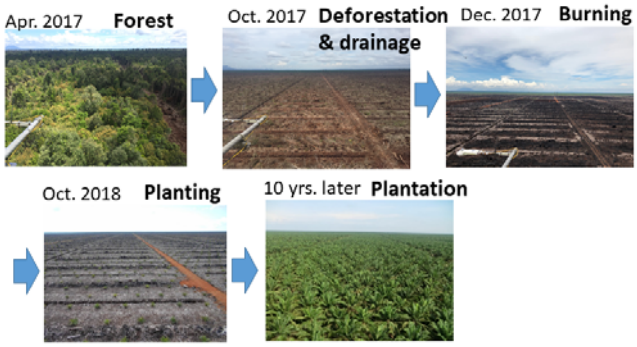

Fig.1 Land conversion in Sarawak, Malaysia.

The objectives of this study are 1) to elucidate the effects of the land conversion and the resultant expansion of oil palm plantations on the carbon pool and the fluxes of greenhouse gases (GHGs), reactive trace gas (BVOC: isoprene) and energy, and 2) to quantify and model the effects of the plantation expansion on the balance of GHGs between the ecosystems and atmosphere and regional climate system.

【Research Methods】

We will establish a tower flux network in tropical peat ecosystems in insular Southeast Asia, including natural and disturbed swamp forests, and oil palm plantations with different ages in collaboration with research institutes in Malaysia, Singapore and Indonesia (Fig. 2). Moreover, we will establish a database, including the fluxes of GHGs (CO_2 and methane (CH_4)), isoprene and energy (sensible and latent heat), meteorological and soil factors, and so on. Using the database, synthesis research will be conducted on the effects of the land conversion on ecosystem functions, such as GHGs balance and energy balance. In addition, we will quantify and model the effects of oil palm expansion on the GHGs balance and climate system in peat areas in Sumatra, Borneo and the Malay Peninsula using satellite remote-sensing, a terrestrial biosphere model (VISIT) and local / regional climate simulation.

Fig.2 Flux tower

【Expected Research Achievements and Scientific Significance】

There were no comprehensive synthesis studies so far on the effects of land conversion to oil palm plantations in tropical peatlands. Therefore, scientifically valuable outcomes on the change of GHGs balance and regional climate is highly expected, including 1) robust emission factors for CO_2 and CH_4, 2) age-averaged GHGs emissions from oil palm plantations by life cycle assessment, and 3) high-resolution land cover mapping using PALSAR data.

【Publications Relevant to the Project】

Hirano T et al., Effects of disturbances on the carbon balance of tropical peat swamp forests. *Global Change Biology*, **18**, 3410-3422, 2012.

Ishikura K, Hirano T, Hirata R et al., Soil carbon dioxide emissions due to oxidative peat decomposition in an oil palm plantation on tropical peat. *Agriculture, Ecosystem and Environment*, **254**, 202-212, 2018.

【Term of Project】

FY2019-2023

【Budget Allocation】

119,200 Thousand Yen

【Homepage Address and Other Contact Information】

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【Grant-in-Aid for Scientific Research (S)】

Broad Section K

Title of Project：Aggregate-biosphere: Unveiling hidden regulatory processes in the oceanic carbon cycle

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Research Project Number：19H05667　Researcher Number：40183892
Keyword：aggregates, genomic analysis, ocean carbon cycling, microbial community, biological carbon pump

【Purpose and Background of the Research】

The sedimentation of organic aggregates is one of the key mechanisms of "biological carbon pump (BCP)", i.e., the vertical carbon transport from the surface to the deep ocean. The BCP facilitates the storage of carbon in the deeper ocean on centennial to even millennial timescales and helps restrain the increase in the atmospheric concentration of carbon dioxide (Figure 1). Traditionally, organic aggregate dynamics have been studied using a physical model, where the role of microbes in the regulation of the BCP has been only superficially taken into account. This paucity of knowledge on complex interactions between microbes and organic aggregates seriously hampers the improvement of our ability to predict the response of oceanic carbon cycle to climate change.

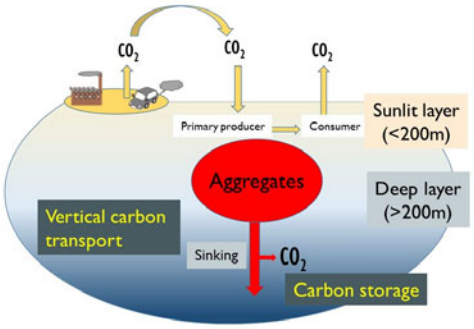

Figure 1. Biological carbon pump

In this research, we propose a new concept "Aggregate-Biosphere" to emphasize the role of diverse microbes, including bacteria, viruses, fungi and protists that flourish on organic aggregates, in exerting influence on their physical structure and dynamics (formation, growth and decay) (Fig. 2). Our goal is to clarify hidden regulatory mechanisms of BCP, involving so-far overlooked actions of the Aggregate-Biosphere. Our research team is composed of the experts from a multitude of scientific fields, including particle dynamics, biogeochemical cycling, microbial ecology, genomic analysis, bioinformatics and mathematical modelling.

【Research Methods】

We conduct field observations, manipulation experiments and mathematical modelling to answer the following three questions concerning the structure, function, and response of the Aggregate-Biosphere. (a) Are there general trends in the compositional pattern of the Aggregate-Biosphere? (b) What are the principal biotic interactions and metabolism that are involved in the regulation of aggregate dynamics? (c) What are the responses of the Aggregate-Biosphere and the BCP to changes in environmental conditions?

【Expected Research Achievements and Scientific Significance】

The expected outcome of this research includes a deeper understanding of the mechanisms by which oceans store carbon and the factors affecting this process. Through this, it contributes to the improvement of our ability to predict future changes in earth's climate and ocean ecosystems. Our research may also reveal a novel feature of the diversity in marine life and its functional consequences. This would contribute to broaden our perspectives concerning the functional role of biodiversity.

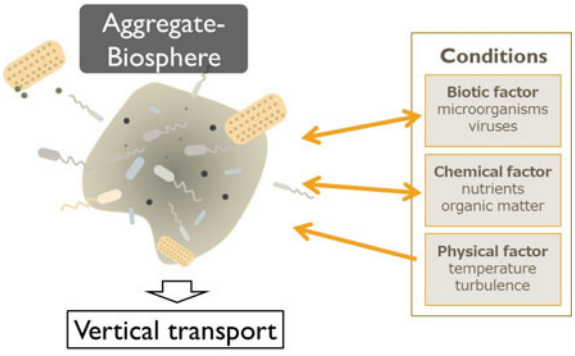

Figure 2. The concept of "Aggregate-Biosphere"

【Publications Relevant to the Project】

・Guidi et al. (2016) Plankton networks driving carbon export in the oligotrophic ocean. Nature, 532, 465-470.
・Yamada et al. (2018) Aggregate formation during the viral lysis of a marine diatom, Frontiers in Marine Science, doi.org/10.3389/fmars.2018.00167

【Term of Project】 FY2019-2023

【Budget Allocation】 154,300 Thousand Yen

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Title of Project：Pan-Arctic Water-Carbon Cycles

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Research Project Number：19H05668　Researcher Number：30283451
Keyword：global warming, Arctic sea ice retreat, atmospheric-terrestrial water cycle, permafrost degradation, greenhouse gases

【Purpose and Background of the Research】

Recent global warming accelerates Arctic sea ice retreat, which derives significant changes in atmospheric-terrestrial water cycle in the Arctic and pan-Arctic regions. Because spatiotemporal variations in emission (or absorption) of greenhouse gases are largely dependent on surface water and vegetation conditions over the terrestrial land surfaces, for better understanding and for better future projection of water-carbon cycles in the pan-Arctic region, it is necessary to conduct an integrated study on atmospheric-terrestrial water-carbon cycles in the region.

The purpose of this research is to integrate atmospheric-terrestrial water and carbon cycles in the pan-Arctic region. We firstly integrate atmospheric- and terrestrial-water cycle models which can calculate spatiotemporal variations in the atmospheric moisture transport, moisture flux convergence, precipitation, vegetation condition, permafrost degradation, and river discharge over the Arctic and pan-Arctic regions, with important boundary conditions of the Arctic sea ice extent. We finally produce spatiotemporal maps of water-covered area, vegetation condition, and fluxes of greenhouse gases. We mainly focus on Northern Eurasia because there are very limited data on the fluxes of greenhouse gases in the region.

【Research Methods】

To achieve above-mentioned goals, we firstly develop a water traceable integrated model (WTIM), based on a water vapor tracer model and a coupled hydrological and biogeochemical model. Then we produce spatiotemporal maps of water-covered area and vegetation condition in Northern Eurasia, using satellite remote sensing data and WTIM products with the help of spatiotemporal data fusion technics. Finally, we estimate spatiotemporal maps on the fluxes of greenhouse gases over Northern Eurasia using a biogeochemical model (Figure 1). To validate the maps, we will continuously measure fluxes of greenhouse gases at eastern Siberia and northern Mongolia.

This study consists of four groups: terrestrial observation group, terrestrial modeling group, atmospheric research group, and integration group. The four groups strongly collaborate each other. We will also organize international scientific symposiums (or workshops) in the research period, and will co-produce our scientific outcomes with Siberian and Mongolian researchers.

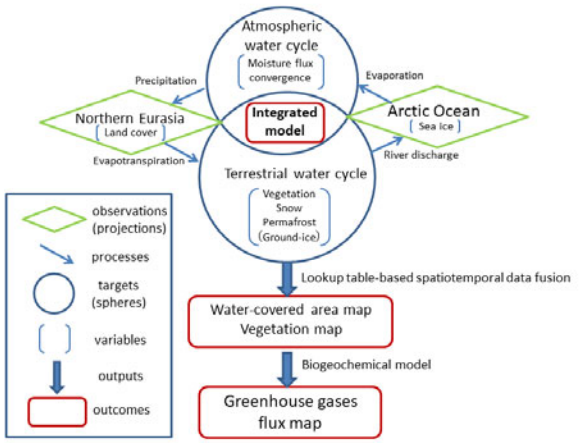

Figure 1 Flowchart of this research

【Expected Research Achievements and Scientific Significance】

This study can reduce uncertainty of the biogeochemical model, and contribute to better understand water-carbon cycles in the pan-Arctic regions. We also contribute to better understand polar amplification in the Arctic and pan-Arctic regions.

【Publications Relevant to the Project】

Hiyama, T. and Takakura, H. (eds.): Global Warming and Human-Nature Dimension in Northern Eurasia. Global Environmental Studies Series, Springer, 224pp, 2018, https://doi.org/10.1007/978-981-10-4648-3

Ohta, T., Hiyama, T. et al. (eds.): Water-Carbon Dynamics in Eastern Siberia. Ecological Studies, 236, Springer, 309pp, 2019, https://doi.org/10.1007/978-981-13-6317-7

【Term of Project】

FY2019-2023

【Budget Allocation】

154,700 Thousand Yen

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【Grant-in-Aid for Scientific Research (S)】

Broad Section K

Title of Project：Assessment on climate impacts of short-lived climate forcers by composition and region with hierarchical numerical models

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Research Project Number：19H05669　Researcher Number：90343326
Keyword：short-lived climate forcer, climate model, climate change, air pollution, aerosol

【Purpose and Background of the Research】

Particulates (aerosols) such as PM2.5 and trace gases such as ozone in the atmosphere are both air pollutants and Short-Lived Climate Forcers (SLCFs). Although the United Nations Intergovernmental Panel on Climate Change (IPCC) has made quantitative assessments of imbalance of energy budget, i.e. radiative forcing, for each of the SLCFs, it has not assessed specific climatic changes such as temperature and precipitation.

In this project we quantitatively evaluate the climate change due to SLCFs by composition and region using the climate models developed by the research team. We also aim for a quantitative understanding of the impact of SLCFs on disasters such as extreme temperature and precipitation that have become apparent in recent years.

【Research Methods】

The following are climate and meteorological models of various spatiotemporal scales used in the project that can calculate transport processes and climate effects of SLCFs (Figure 1).

> MIROC-SPRINTARS/CHASER: A climate model which simulates the basic global climatic conditions with a horizontal resolution of several tens of km combining SPRINTARS, which calculates processes related to aerosol, and CHASER, which calculates detailed chemical reaction processes. MIROC-SPRINTARS is also used in the PM2.5 forecast, which is widely available to the general public daily.

> NICAM-Chem: A climate/meteorological model which calculates global atmospheric conditions expressing cloud processes explicitly with a horizontal resolution of 3.5/7/14km combining SPRINTARS/CHASER for calculating the climate effects of SLCFs.

> SCALE-LES: A meteorological model with a horizontal resolution of tens to hundreds of meters that can directly handle cloud processes, which is used for obtaining he knowledge to improve the expression of clouds in climate models.

In the calculations using these climate models, the emission amount related to each SLCF is perturbed, and the changes in the meteorological field such as temperature and precipitation are analyzed. At that time, the calculations are carried out while refining the cloud and precipitation process through improvement of the expression of aerosol-cloud interaction and introduction of a method to prognose raindrops and snowfall.

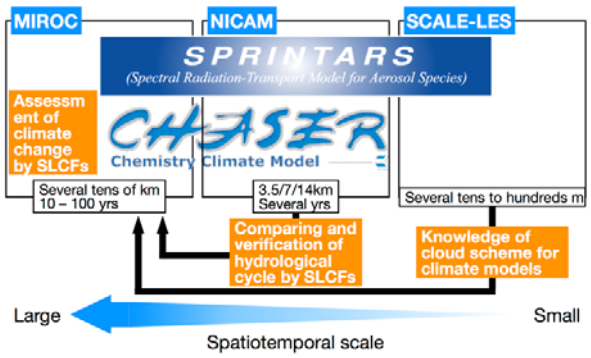

Figure 1　Hierarchical numerical models in this project.

【Expected Research Achievements and Scientific Significance】

It will create the new research area on an unresolved problem of quantitative impact assessment of climate change by SLCFs through this project in which the atmospheric physics on clouds and precipitation is combined with the atmospheric chemistry. It is an advantage that research can be promoted with understanding the mechanism of the climate impact of SLCFs obtained at the development stage of the numerical models developed by members of this research team themselves. It is expected to make concrete recommendations on mitigation of both climate change and air pollution, which are major international environmental issues.

【Publications Relevant to the Project】

Takemura, T. and K. Suzuki: Weak global warming mitigation by reducing black carbon emissions. Sci. Rep., 9, 4419, doi:10.1038/s41598-019-41181-6 (2019).

Suzuki, K. and T. Takemura: Perturbations to global energy budget due to absorbing and scattering aerosols. J. Geophys. Res., 124, 2194-2209, doi:10.1029/2018JD 029808 (2019).

【Term of Project】

FY2019-2023

【Budget Allocation】

153,900 Thousand Yen

【Homepage Address and Other Contact Information】

https://www.riam.kyushu-u.ac.jp/climate/indexe.html